Module -2

SOLUTION, VOLUMETRIC ANALYSIS & WATER

Solution is a homogeneous mixture of two or more than two non-reacting components. (A system is aid to be Homogeneous if it has uniform composition and properties throughout). Solute is the component that dissolves in the solvent in a solution.
Solvent - The medium in which the solute dissolves.
In a binary Solution, the component which is smaller in amount is the solute and that present in larger amount is called the solvent.

Method of expressing concentrations of a solution -

a) **Molarity (M)** – Molarity is the number of moles of solute dissolved in one litre of solution.

$$Molarity \ \ M = \frac{w \times 1000}{m \times V}$$

Where w is the weight of solute in gram, m is molecular mass of solute and V is volume of solution in ml

b) **Normality (N)** - Normality is the number of gram equivalents of solute dissolved in one litre of solution.

$$Normality \ \ N = \frac{w \times 1000}{E \times V}$$

Where w is the weight of solute in gram, E is the equivalent mass of solute and V is volume of solution in ml

Equivalent weight of an acid is the weight of acid which contains one replaceable hydrogen atom.

Equivalent weight of a base is the weight of base which contains one replaceable hydroxyl ion.

c) **Parts per million (ppm)** – It is the number of parts by mass of solute per million parts by mass of solution.

$$ppm = \frac{Mass\ of\ solute}{Mass\ of\ solution} \times 10^6$$

Ionic product of water –

Water undergoes self ionisation reversibly to a very small extent producing H^+ and OH^- ions.

$$H_2O \rightleftharpoons H^+ + OH^-$$

Ionic product of water, K_w,, is defined as the product of the concentrations of H^+ ions and OH^- ions in water

Mathematically, $\mathbf{K_w = [H^+] \times [OH^-]}$, (where K_w is called ionic product of water, $[H^+]$ and $[OH^-]$ are the molar concentrations of H^+ ions and OH^- ions respectively)

In pure water $[H^+] = [OH^-] = 10^{-7}$ moles per litre at 25 °c

Therefore $K_w = [H^+] \times [OH^-] = 10^{-7} \times 10^{-7} = 10^{-14}$ moles^2 / Litre^2 at 25° C

In neutral solution $[H^+] = [OH^-] = 10^{-7}$ moles per litre at 25 °c

In acidic solution $[H^+] > [OH^-]$ and In basic solution $[H^+] < [OH^-]$

pH of a solution – pH of a solution is defined as negative logarithm to base 10 of hydrogen ion concentration in moles per litre. It is a method of expressing hydrogen ion concentration of a solution.

$pH = -\log_{10}[H^+]$

$[H^+]$ in pure water is 10^{-7} moles per litre at 25^0C

Therefore PH of water at $25^0C = -\log_{10}[H^+] = -\log_{10}10^{-7} = (-7) -\log_{10}10 =$ **7**

For acidic solution pH is less than 7, and for basic solution pH is greater than 7

Applications/ importance of pH value –

1. To find acidic, basic or neutral nature of a solution.
2. Selection of pH can reduce the rate of corrosion. Eg. In boilers
3. pH of human blood is 7.36 to 7.42, A change in pH by 0.2 units results in death.
4. Calculation of hydrogen ion concentration.
5. In agriculture to find the type of fertilizers to be applied pH of soil is important.
6. In digestive system.
7. In textile industry and sugar industry
8. During the production of potable water, alum is added in the slightly acidic pH.
9. pH influences the quality of deposits in electroplating.
10. pH is important in food preservation

pOH of Scale – pOH of a solution is defined as the negative logarithm to base 10 of hydroxyl ion concentration in moles per litre.

$pOH = -\log_{10}[OH^-]$

$[OH^-]$ in pure water is 10^{-7} moles per litre at 25^0C

Therefore pOH of water at 25^0C = $-\log_{10}[OH^-]$ = $-\log_{10}10^{-7}$ = $(-7)\,-\log_{10}10$ = **7**

For a solution at 25^0C, pH + pOH = 14, and therefore

pH = 14 - pOH , and pOH = 14 - pH

Buffer solution – Solutions which can resists the change in pH when small amount of acid or base is added in to it is called buffer solution. There are two types of buffer solutions, acidic buffer and basic buffer.

Acidic buffer – It is obtained by mixing a weak acid and its salt with a strong base. Eg. (1) Acetic acid and sodium acetate. (2)Carbonic acid and sodium carbonate

Basic buffer – It is obtained by mixing a weak base and its salt with a strong acid. Eg. Ammonium hydroxide and ammonium chloride.

<u>Dilution formulae</u>

When a solution (Acid or Base) is diluted by adding water, it obeys the relation,

$\mathbf{N_1V_1 = N_2V_2}$, Where N_1 is the initial normality, V_1 is the initial volume, N_2 is the final normality, and V_2 is the final volume. (For Eg, if 0.1 normal 100 ml HCl is diluted to 200 ml by adding 100 ml of water, then the normality of resulting solution will be 0.05. Because $N_1V_1 = N_2V_2$ or, $0.1 \times 100 = N_2 \times 200$ or $N_2 = 0.05$)

Volumetric analysis – It is a quantitative analysis involving measurement of volume of liquids. According to the law of chemical equivalents, substances react in the ratio of their equivalent weights.

Mathematically it can be expressed as , $\mathbf{N_1V_1 = N_2V_2}$

Where N_1 and N_2 are the normalities and V_1 and V_2 are the volumes of solutions of substances 1 and 2 which react completely.

(for acid base reaction substance 1 is acid and substance 2 is base or vice versa)

Standard solution – A solution of known concentration is called standard solution

Titration – It is the process of adding slowly a solution from a burette to a known volume of another solution until the reaction just completed.

End point - the point at which the indicator shows colour change during a titration is called end point. Or equivalence point determined with indicator is called end point

Acid - base indicator is a weak acid or base which give different colour at different pH.

Indicator	**pH range**	**Colour**	
		Acid Medium	**Basic Medium**
Phenolphthalein	8.3 - 10	Colourless	Pink
Methyl Orange	3.1 – 4.5	Orange red	Yellow
Litmus	4.5 – 8.3	Red	Blue

Choice of indicators in acid – base titrations -

Titration of strong acid against strong base – Eg. HCl vs NaOH, The pH change towards the end point of this type of titration is roughly from 10 to 3.5 , Hence both phenolphthalein and methyl orange can be used as indicators.

Titration of strong acid against weak base – Eg. HCl vs Na_2CO_3, The pH change towards the end point of this type of titration is roughly from 7.5 to 3.5 , Hence suitable indicator for this titration is methyl orange.

Titration of weak acid against strong base – Eg. CH_3COOH vs NaOH, The pH change towards the end point of this type of titration is roughly from 10 to 6.5 , Hence suitable indicator for this titration is phenolphthalein.

Titration of weak acid against weak base – Eg. CH_3COOH vs Na_2CO_3, There is no sharp pH change towards the end point of this type of titration. Hence none of the indicator can give correct result and such titrations are not done using acid – base indicators.

WATER

Soft Water – Water which produces lather readily with soap solution is called soft water

Hard water - Water which does not produces lather readily with soap solution is called hard water

Hardness of water is due to the dissolved impurities such as bicarbonates (HCO_3^-), chlorides (Cl^-) and sulphates ($SO4^{2-}$) of calcium and magnesium.

Why hard water do not form lather with soap – Ordinary soaps are sodium salts of fatty acids (RCOONa). When treated with hard water, soap reacts with dissolved ions (Ca and Mg) to form the insoluble salts (scum) of calcium and magnesium **{** $(RCOO)_2Ca$ and $(RCOO)_2Mg$ **}.** Therefore hard water do not form lather with soap.

Distinction between Soft water and Hard water

	Soft water	Hard water
1	Gives lather with soap readily	Does not give lather with soap readily
2	Does not form insoluble scum with soap	Form insoluble scum with soap
3	Does not contain calcium and magnesium salts	Contain calcium and magnesium salts

TYPES OF HARDNESS - **Temporary Hardness & Permanent hardness**

A) **Temporary Hardness** - It is due to the presence of dissolved bicarbonates of calcium and magnesium.

B) **Permanent hardness -** it is due to the presence of dissolved chlorides and sulphates of calcium and magnesium in water.

Hardness can be removed by

i) **Soda lime Process** – In this process required amount of slaked lime ($Ca(OH)_2$), and Soda (Na_2CO_3) are added to hard water to convert the soluble Calcium and Magnesium ions to insoluble carbonate (CO_3^{2-}).

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2\,CaCO_3 + 2H_2O$$

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + 2NaCl$$

ii) **Ion exchange method** - in this method hard water is first passed through a tank with a bed of cation exchanger (**E-H**) where all positive ions are exchanged with H^+ ions.

$$2\,E\text{-}H + Ca^{2+} \rightarrow E_2Ca + 2H^+ \quad , \quad \& \quad 2\,E\text{-}H + Mg^{2+} \rightarrow E_2Mg + 2H^+$$

The water coming out of cation exchanger is then passed through a second tank containing anion exchanger (**E-OH**) where all the anions are exchanged with OH^- ions.

$$E\text{-}OH + Cl^- \rightarrow E\text{-}Cl + OH^- \quad \& \quad 2E\text{-}OH + SO_4^{2-} \rightarrow E_2SO_4 + 2OH^-$$

The cation exchange resin is regenerated by using acid and anion exchange resin is regenerated by using alkali.

Disadvantages of Hard water

a) Formation of boiler scale - **Hard water on boiling deposits a hard scale(crust) on the inner walls of the boiler and steam pipes. This deposit is called boiler scale**. The boiler scale formed is insulating and leads to wastage of fuel.
b) **Boiler explosion** – sometimes the boiler scale cracks and the water suddenly comes in contact with the overheated iron plates of the boiler. As a result, large volume of steam is formed suddenly and a high pressure is developed inside the boiler. This may lead to the boiler explosion.
c) Corrosion - The chlorides present in hard water gets hydrolysed producing free hydrochloric acid. This acid corrode the metal with which the boiler is made

$$MgCl_2 + H_2O \longrightarrow Mg(OH)Cl + HCl$$

Potable water

Water which is safe to drink is called potable water. Potable water need not be pure water like distilled water.

Characteristics of potable water are,

1. It should be clear and odourless
2. It should be free from disease producing micro organisms
3. It should be free from disagreeable gases like H_2S, NH_3 and minerals like nitrites.
4. It should be free from suspended impurities
5. Total dissolved solids should be less than 500ppm.
6. It should be reasonably soft.

Treatment process to make potable water

Purification of water involves the following steps

Screening, Sedimentation, Coagulation, Filtration, and sterilization

1. **Screening** - The raw water is passed through bar screens or mesh screens to remove the larger sized impurities
2. **Sedimentation** - In this process water is allowed to stand undisturbed to settle down the suspended impurities.
3. **Coagulation -** Finely divided suspended particles are made to settle down by adding certain chemicals (coagulants) like alum, ferric chloride, sodium aluminate etc.
4. **Filtration** - In this process the insoluble colloidal and bacterial impurities are removed by means of filters. Two types of filtrations commonly used in water treatment are
   - **(a) Operation of gravity sand filter** – In this method water is allowed to pass through a filtering medium consisting of fine sand, coarse sand, and graded gravel.
   - **(b) Operation of pressure filter** - In this method water at high pressure is allowed to pass through the gravity sand filter.
5. **Sterilization (disinfection)** - The process of destroying the disease producing bacteria and micro organisms is called Sterilization or disinfection. It can be done by following methods.
   - **(a) Sterilization by chlorine** - In this method chlorine water or chlorine gas is passed through a tank containing water. This method is very economical and leaves no solid impurities when treated with water. However the main disadvantage is that excess chlorine if present causes unpleasant odor and taste and irritation in the mucous membrane.
   - **(b) Sterilization by bleaching powder** -- Bleaching powder is calcium oxy chloride ($CaOCl_2$) which when reacts with water release nascent oxygen. Nascent oxygen is a powerful germicide.(Nascent oxygen means atomic oxygen produced in a reaction)

$$\mathbf{CaOCl_2 + H_2O \rightarrow Ca(OH_2) + Cl_2}$$

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

$$HOCl \rightarrow HCl + (O) \text{ Nascent oxygen.}$$

(c) Sterilization by ultraviolet radiation—

Ultraviolet rays can kill all the pathogenic bacteria present in water.

Schematic representation of different steps involving the production of potable water